controlling the quality of the product.

Rapid and accurate instruments are required to measure moisture content, color, tenderness, maturity and other important quality factors. Some of them have been developed by cooperative effort of instrument makers and biological scientists. The biological scientists have determined the types of measurements required to express the quality of the product. Specialists in instrumentation have developed methods for making the measurements. So we have automatic machines for sorting lemons, beans, peas, and seeds by color, and for sorting eggs to reject those with defects.

The development of new instruments and procedures will open up larger fields for the application of engineering to biological problems in agriculture.

# Costs of Farm Machinery

James Vermeer and Donald T. Black

THE LARGEST single item of expenditure on many farms in the United States is the cost of owning and operating farm machinery.

Of 30 typical farm situations in the United States, machinery costs in 1958 were more than 40 percent of total operating expenses on three-fifths of the farms. On some farms they made up nearly two-thirds of all operating expenses.

Expenditures for operating and replacing machinery among 30 types of the commercial family-operated farms ranged from about 400 dollars on small tobacco farms in the Coastal Plain of North Carolina to 6,700 dollars per farm on irrigated cotton farms in the High Plains of Texas. The average of the 30 types of farms was about 2,500 dollars.

The value of machinery by type of farm was 1,300 dollars to 18 thousand and averaged 6,600 dollars at the current value. The original purchase price probably was about twice as great. As prices of machines have risen since those investments were made, the cost of replacing 6,600 dollars' worth of equipment at 1960 prices probably would require an investment of 15 thousand to 17 thousand dollars.

Prices farmers paid for motor vehicles and farm machinery were about 2.5 times as high in 1960 as in 1940. For example, prices of 20–29-horsepower wheel tractors rose from 1,020 dollars in 1940 to 2,470 dollars in 1959. The 1940 and 1959 models were not identical, of course; the newer models have extras, such as generators, batteries, self-starters, lights, power takeoffs, power steering, hydraulic controls, and more comfortable seats. Thus the differences in cost of 1940 and 1959 tractors are not due solely to higher prices in 1959.

Many of the improvements in the machines perform more effectively the job for which the machines were designed or reduce the heavy physical labor required of farmworkers. In either case, costs of owning and frequently costs of operating machinery have risen. At the same time, improved machines have contributed to greater output, and machinery costs per unit of product have risen less than the total machinery costs.

THE COSTS of owning machinery often are referred to as fixed costs. All other costs are labeled variable costs.

Some costs are fixed, regardless of amount of use—the interest on investment, taxes, insurance, housing, and usually depreciation. Variable costs include fuel or power costs, repairs, lubrication, and service labor. Some variable costs are proportional to use. Others change with use but are not necessarily proportional to it.

All costs do not fit neatly into these two categories. Depreciation, for example, is classified usually as a fixed cost. As long as the rate of obsolescence exceeds the rate at which the machine wears out, this is a proper classification. If a machine is used so much that it is worn out before it becomes obsolete, however, depreciation becomes a variable cost.

Some ownership costs are applicable to all machines of a given type and size regardless of age or condition. Housing costs are of this kind, because the space required to house a machine of a given size is independent of its age or value. The cost of a license required on trucks, in States where the cost of a license is distinct from personal property tax, likewise is uniform regardless of the age and depreciated value of the truck.

Other ownership costs are related to value and become fixed once the machine is acquired. Taxes and insurance are examples. Usually they are independent of the extent of its use.

Insurance sometimes is considered as a cost only if a machine is insured, but most farmers realize that if they do not insure their machinery against accidental damage or loss through an established insurance company, they in effect carry their own insurance—they must be prepared to suffer some losses, and frequently do.

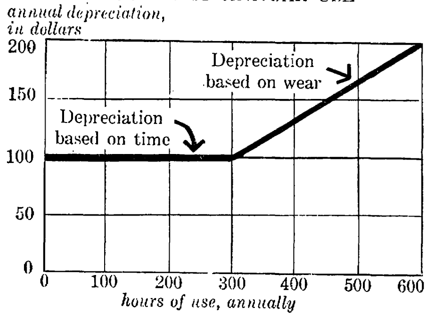
Another cost related to value is the interest charge on money invested in machinery. This cost often is overlooked, except perhaps for the actual interest paid on money borrowed to buy a machine.

These costs related to value can be kept to a minimum by farmers who can keep older machines in good repair through careful use and regular maintenance. As long as the older machines do not become obsolete—because of the introduction of new machines that will do the job faster or replace more labor—farmers will find it profitable to use older machines with lower charges for taxes, insurance, and interest.

Fixed costs, or costs of ownership, are higher for new equipment. Variable costs, or costs of operation, are higher for old or used equipment.

Fixed costs per hour or per acre of use are higher for equipment that is used only a few days during a year.

ANNUAL DEPRECIATION OF SMALL TRACTORS WITH DIFFERENT AMOUNTS OF ANNUAL USE




*Charges for depreciation are constant when the rate of obsolescence exceeds wear and tear. They are proportional to use when wear and tear exceeds the rate of obsolescence.*

Depreciation is one of the major costs of owning machines on most farms.

It is one of the most difficult cost items to estimate. Depreciation occurs for one or both of two reasons.

If a machine is used very little, usually it becomes obsolete before it is worn out. The original cost therefore must be charged off when the machine is replaced.

On the other hand, extensive use will cause the machine to be worn out while it is still the best kind of machine for the job. Again, the original investment in the machine has been used up and must be charged off.

Estimating the expected life of a machine is a highly subjective procedure at best. Records of experience with similar machines are of some help. They indicate the hours or years of use to be expected before the machine is worn out, but they are of little help in forecasting when a particular machine will become obsolete.

Because obsolescence does occur, a

farmer has to make a minimum charge for depreciation even though he uses the machine very little. If the machine is used so much as to shorten its expected life, however, annual depreciation will exceed the minimum charge.

For example: A machine costs 1,500 dollars and its expected life is 15 years, or 4,500 hours, of use, whichever occurs first. Based on the expected life of 15 years, depreciation would be 100 dollars a year. If the annual use exceeds 300 hours (4,500 hours divided by 15), the machine will not last 15 years, and the depreciation charge will exceed 100 dollars. If the machine is used 500 hours a year, its useful life will be reduced to 9 years (4,500 hours divided by 500) and the depreciation charge will be 167 dollars a year (1,500 dollars divided by 9).

A depreciation charge for a machine used very little thus is a fixed cost.

Using a machine enough so that the depreciation from wear is as great as the rate of obsolescence, however, reduces one of the major costs of owning a machine to its practical minimum for each hour of use. Depreciation charges beyond that point are proportional to use—wear.

Some other fixed costs are reduced if a machine is used in excess of the amount necessary to reduce depreciation cost per hour to its practical minimum. Using a machine enough to increase the annual depreciation, and thus reduce the remaining value, more rapidly, reduces charges for interest, taxes, and insurance, which relate to value.

Nearly all new machines are designed to increase the volume of work one man can do. Sometimes they reduce the cost per unit of work performed if a big enough volume of work can be found for them. Associated with the greater capacity of machines has been the demand for more land to increase the size of farms so as to provide more work per machine. Greater demand for land has led to higher prices of land. This is an indirect cost of owning larger machines.

One way to reduce costs of machinery is to develop cheaper machines that will perform the same volume of work as the machines now in use. Perhaps too little emphasis has been given to this aspect of machine design. In order to reduce fixed costs, or the costs of owning them, the new models would need to be sold for less money than their predecessors.

The design and use of multipurpose machines serve to hold down the fixed costs of machinery per farm. Tillage machines are of this type. They are relatively inexpensive and are commonly used to prepare the seedbed and cultivate all crops on a farm.

Multipurpose harvesting machines have been put on the market. Forage harvesters, with slight adaptations, can be used to harvest green feed from standing grass and legumes, wilted grasses for silage, hay, and row crops, such as corn and sorghum for silage. Combines can be adapted to harvest small grains, soybeans, and corn for grain.

Adapting machines to a number of tasks extends their use and reduces overhead costs per acre or hour of use.

Costs of owning and operating machinery usually are not considered independently in deciding which machines or methods to use in performing specified jobs.

Other factors to consider are: What effect the use of a given machine has on other costs, particularly labor; whether the new machine or method will do a better job than the present method does; and whether the capital invested in machinery could be used more advantageously in some other investment or enterprise.

If two types of machines replace equal amounts of labor, the one that replaces hired labor is more likely to be adopted than one that replaces family labor.

Some machines do not necessarily reduce the number of man-hours required; often they make the work easier. If a machine enables a boy or girl in the farm family to replace a hired man, the likelihood is greater that the machine will be adopted.

Other machines can replace hired or family labor. They have an economic advantage on farms operated largely with family labor, however, only if the available labor can be profitably employed in some other way or if the family is willing to use this method to buy leisure.

MACHINERY costs may possibly be reduced by the use of alternative practices or systems for getting a job done.

Some machines may be eliminated entirely or may be used for more than one purpose. The combining of operations and machines allows the job to be done faster when timeliness is advantageous and cuts the labor as well. Combinations of operations and reduction in costs go hand in hand. An example is the combined operation of mowing and conditioning of forage for hay. With both the mower and conditioner attached to one tractor, the number of acres handled per hour by one operator and tractor is nearly twice as great as when the operations are performed separately.

Before a new practice is adopted it must satisfy either or both of the following requirements: It must serve to lower costs; the quality of the work the new system does must be as high or higher than that done with the existing practice.

If it meets only one of these—for example, if it reduces costs but also reduces quality—the reduction in costs must be at least as great as the reduction in value of the product.

FORAGE feed crops rank second to corn in value among all farm crops grown in the United States. About 120 million tons of hay and 80 million tons of silage are produced annually.

Methods for harvesting forage have changed rapidly since 1945. The field chopper, forage blower, field baler, hay drier, and a wide variety of other machines have come into general use. Complete pushbutton feeding equipment is a reality—a great change from the day when haying was done with a mower, dump rake, wagon, and several hand forks. On farms where harvesting forage is a major operation, investments in machinery for this job may be as much as 15 thousand dollars for a single farm.

Because of the importance of forage crops on a large proportion of farms and the opportunities for reducing costs of producing forage by proper combinations of equipment, we pay particular attention here to the harvesting of forage to exemplify ways to reduce costs of harvest.

Among the new methods of harvesting forage are green chopping, by which pasture forage is cut and brought to the animals and fed green; hay drying, either in storage or in a batch system, such as drying on one or more wagons; chopping dry hay in the field and moving it to storage mechanically; and several techniques for preserving the crops as silage.

In determining which of the various systems and necessary equipment are most suitable for his farm, the farmer must consider the two basic items—cost and quality. He should consider also the volumes or amounts of materials to be harvested; amounts of hay, grain, silage, and pasture fed and the number of livestock; the basic layout of the farmstead, hauling distances, and storage and feeding structures; and the additional equipment required for the new practice and its potential use in other new practices.

In harvesting hay, results of research at Iowa State University and elsewhere have shown that the lowest cost method is with the sweep rake, a buck rake, and buck stacker. Where hay must be brought to a central feeding location or sold commercially, this practice obviously must be replaced with some such method as baling to reduce volume and provide easier handling.

If the hay is to be fed on the farm, forage harvesters may be used for harvesting both hay and silage; the same associated equipment such as the mower, rake, and forage blower may be used for handling both types of forage.

As we mentioned before, the tandem operation of mowing and conditioning the hay or (for making silage) both mowing and raking may be performed by one tractor operation.

For farms handling large tonnages of forage, a new self-propelled windrower offers additional savings in cost of equipment and labor. It can mow, condition, and rake a 10- to 14-foot swath in one operation.

Because of the increased interest in the production of better hay through preservation of nutrients during the harvesting and storage phases, artificial drying and practices that speed up natural drying have become common, especially in the East and in sections where weather makes field curing hazardous. Forage begins to deteriorate as soon as it is cut. Deterioration continues rapidly until the crop is completely cured. To reduce the curing time, higher expenditures for equipment have been made for such items as conditioners and drying equipment.

A survey by men at Cornell University revealed that the average cost of drying 1 ton of hay with a heated-air drier was about 6.50 dollars. Fixed costs per ton ranged from 1.15 dollars to 16.06 dollars, while variable costs were 83 cents to 6.20 dollars. Total drying costs for drying in the mow with unheated air, as reported by men at the University of Delaware, were 1.54 dollars to 6.54 dollars a ton.

Variations in cost are due to the type of equipment and the drying system used, the amount of moisture removed, and the number of tons of hay dried. For optimum operating costs in hay drying, the minimum amount of hay appears to be in a range of 75 to 100 tons.

GRASS SILAGE has increased in popularity as a method of harvesting and storing forage crops, primarily because of the recent introduction of direct-cut forage harvesters. The direct-cut system has great appeal to the farmer because it is a once-over operation. This practice, however, results in a high-moisture silage, which means large quantities of water must be hauled for each ton of dry matter stored.

Studies conducted by men of the Department of Agriculture showed that making grass silage by the wilting method requires fewer man-hours per ton of dry matter stored than the direct-cut method. More acres can be cut and stored in an hour, and therefore a large crew is required for a shorter period of time. This method requires equipment for mowing and raking, but such machinery also may be used for haying.

Feeding trials showed that wilted silage was equal to good field-cured hay and superior to weather-damaged hay but had a slightly lower feeding value than barn-dried hay.

GREEN CHOPPING is a way of feeding forage whereby the entire plant growth is cut and fed without drying, curing, or storing. Greater utilization of the forage is possible than with rotation grazing or with continuous grazing, the common method. Losses from selective grazing, trampling, and spoilage from droppings are avoided.

Obviously, however, livestock themselves provide the cheapest method of harvesting, and any degree of mechanization involves additional costs. Green chopping is no exception. A forage harvester and hauling and feeding equipment are necessary. Additional power and labor may be required, and the daily chore of chopping and hauling may interfere with other farm operations.

These additional costs may be offset by increases in income through increase in the size of herd arising from the additional forage available or by reductions in feed costs when more forage can be economically used in the ration. Green chopping may also be used to spread overhead costs to the point at which a forage harvester is economical, whereas it could not be justified solely for use in making silage.

THE MARCH of mechanization requires the use of increasing amounts of capital. Many farmers do not have, cannot borrow, or do not want to risk additional capital for this purpose. Others prefer to use available capital to buy feed, fertilizer, and livestock or for other capital items where the returns per dollar invested may be greater than the return from investment in additional machinery. They are able, however, to take advantage of some of the benefits of mechanization by hiring, renting, borrowing, exchanging, or owning jointly labor-saving machines.

Among the methods used by farmers to reduce their individual investments in machinery, custom work is one of the commonest. About 150 farm operations are performed by custom operators.

Custom work enables a small farmer to obtain the advantages of mechanization without incurring the high overhead costs of owning a specialized machine solely for his own use. These advantages can be obtained in either of two ways. A farmer can hire specified jobs done for him, or he can buy a specialized machine for his own use and spread his ownership costs by doing custom work for neighbors.

If enough custom work is available, the latter method might be preferable. It gives the small farmer an opportunity to sell some of his own labor and the use of his other equipment. By hiring custom work, he would be hiring additional labor and other equipment—for example, a tractor—while his own labor and tractor remained idle.

Rates charged for custom work vary greatly from one part of the country to another. Generally they have been lowest in the North Central States and highest in the Pacific Coast States. In 1957, for example, custom charges for picking corn were about 4.75 dollars an acre in the north-central region, about 6.75 dollars in the Northeast, and 8 dollars in the Pacific Coast States. Costs of operating the machines including a charge for labor may have been lower in the Corn Belt than in the Pacific Coast States, but the differences in costs probably were not so great as the differences in custom charges.

The supply of custom operators and their machines and the demand for their services establish the rates. The availability of machines and operators willing to do custom work, on the one hand, and the number of farmers wanting the services of custom operators, on the other, are major considerations.

In the Corn Belt, there were only 72 acres of corn to be picked in 1958 for each machine on farms on January 1, 1958. In the Pacific Coast States, the ratio was 161 acres to one machine. This is one of the factors causing lower custom rates in the Corn Belt than in the Pacific Coast States.

In some areas and among some farmers, custom work is done chiefly as an accommodation for neighbors. Consequently the rates charged are not intended to cover all costs but are only a basis of settlement among neighbors. It may be advantageous there for small operators to hire custom operators to do the jobs that require the use of expensive machines.

The cooperative ownership of machines provides another way of reducing investment per farm and spreading the fixed costs over a larger volume of work.

Because harvesting machines require relatively large investments and are used only a few days a year, they are the ones that are most frequently owned cooperatively. For cooperative ownership to be successful, however, stability of tenure of the operators is highly desirable. The timing of the use of machines on the cooperating farms also requires some planning. For example, two or more farmers could use one combine if they planted some early, midseason, and late maturing varieties of small grains and soybeans. Some jobs, such as filling silos, usually require more help than is available on one farm. The cooperative ownership of silo-filling equipment is a natural arrangement among farmers who exchange work.

LEASING equipment to farmers is a recent addition to the business of some farm machinery dealers. Renting machinery instead of owning it enables farmers to avoid investment in expensive equipment.

Farmers also have the advantage of obtaining the use of only the equipment they need. Renting a specialized machine frequently enables a farmer to make fuller utilization of his own labor and equipment.

If the job can be completed within the time limit of the rental agreement, the farmer has the same control over the time and the way the job will be done as he would have if he owned the equipment. Under unfavorable conditions or adverse weather, however, the lease may expire before the job is done. If the lease cannot be renewed, the loss of a crop or failure to get a job done on time may be greater than all the costs of ownership. Also, because of unfavorable weather, a farmer may have to pay rent on a machine without being able to use it.

The practice of renting machines to farmers also has some advantages for dealers in addition to the income from renting. It gives farmers an opportunity to try machines, and not infrequently they decide to buy.

Rented machines are not always operated properly. Sometimes dealers can improve operating methods by giving farmers instruction in correct operating methods.

The cost of renting machines varies widely from one locality to another. In many communities rental machines are unavailable.

Paul M. Mulliken, of the National Retail Farm Equipment Association, suggested the following rates in an article published in Farm Equipment Retailing, in November 1957:

1 percent of the new delivered retail price of equipment for a 10-hour day.

5 percent of the new delivered retail price for a week.

15 percent on the same basis for a month.

25 percent for a 2-month period.

33.3 percent for 3 months.

The formula applies only to the use of the equipment. Extras, such as an operator, fuel, delivery and pickup service, and supplies, would require added charges. Owners of the machines would be responsible for the usual wear and depreciation, but renters would assume liability for accidents and abuse.

Mr. Mulliken indicated that, to his knowledge, this schedule of rates had not been used by any dealer.

Since then, the published rates of one dealer have come to our attention. In general, rates charged for the use of tractors approximate those suggested here, but rates charged for tractor implements and other equipment were 4 to 6 times as high as those suggested by Mr. Mulliken—an indication that the rates should not be uniform percentages of retail prices. It is likely that costs of sharpening and replacing worn parts on plows, cultivators, mowers, and saws are much higher relative to the retail prices of such equipment than repairs on tractors are relative to their retail prices.

The wide range in rates that are likely to prevail in a new type of service indicates that choice between renting a machine, and owning it, individually or cooperatively, depends largely on local conditions.

Each farmer must estimate what it would cost him to own a machine per unit of the work that he has for it from year to year. If this cost is greater than rental charges in his community, he should consider renting. If costs of owning are less than rental charges, there is little advantage in renting.

TIMELINESS of any operation—harvesting for instance—is an important factor in determining whether to own or lease equipment or rely on custom work.

It may also be important in determining whether to purchase increased-capacity equipment, such as a 10-foot mower rather than the 7-foot model.

Until such time as we can obtain more control over its uncertainty and its effect on crops, weather is a problem that must be contended with. The ownership of any machine or trading for a machine with greater capacity than needed for an average year may be justified on the reasoning that an unfavorable season could mean the difference between a good crop and a poor crop or no crop at all.

A farmer's decision on whether to buy, lease, or hire the job done must be based on the costs involved and his estimate of the risk involved. He may also wish to consider the possibility of alternative practices, such as the making of grass silage when time and weather are not good for curing hay in the field.

Costs of owning machinery can be reduced by the proper selection of the kind and size of machines for the jobs to be done, and by spreading these ownership costs over a sufficient volume of work so that each machine is worn out in normal use before obsolescence becomes significant.

# Management of Machines

Kenneth K. Barnes and Paul E. Strickler

MANAGEMENT of machinery is an important part of farm management. It has become one of the more flexible factors in the control of costs of crop production.

A typical breakdown of the annual costs of producing corn in the Corn Belt would allot 20 dollars an acre to land, 10 dollars an acre to seed and fertilizer, and 20 dollars an acre to costs of labor and machinery. A farmer cannot control the prices of inputs, which are set basically in the marketplace. In selecting and operating machinery, however, he has a wide latitude in the substitution of capital for labor and in the control of per acre costs of machines.

The engineering advances that each year bring improved machines tend to make the machinery-management job more complicated. On what basis should a farmer in the Corn Belt, where four-row planting and cultivating has been standard, decide to buy a 12-row unit? He must select the most profitable size of machine for his operations. The designer of farm machinery must predict the sizes of machines that will be in demand as patterns of agricultural production change.

The decisions cannot be soundly made, and machinery cannot be managed effectively without an understanding of the factors that influence the capacities of machines to accomplish jobs in the field.

THE FIELD capacity of a machine is a function of the forward speed and operating width and of the time losses associated with the operation.

The theoretical field capacity is the rate at which a machine would do a job if there were no interruptions—no clogging, turning, slowing, or filling of hoppers. This capacity is expressed in terms of acres per hour.

The effective field capacity is the average rate at which the operation really moves. If, for example, at the end of 10 hours of picking cotton 8 acres have been picked, the effective field capacity is .8 acre per hour. The effective capacity is less than the theoretical capacity because of the time spent turning at row ends, emptying baskets, and cleaning out the picker.

THEORETICAL field capacity is the forward speed multiplied by the operating width of the machine. The theoretical field capacity (in acres per hour) equals the product of the forward speed